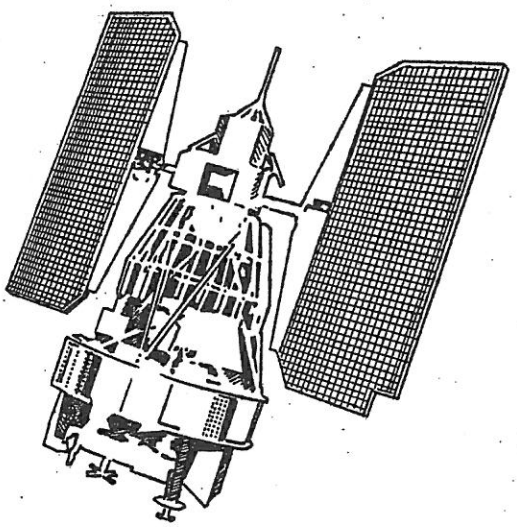
REPORT OF INVESTIGATIONS NO. 79-8

EVALUATION OF LANDSAT IMAGERY AS A TOOL FOR PETROLEUM EXPLORATION



BY

VELON H. MINSHEW, TSEAN-SHU P. LEE,
CONRAD A. GAZZIER

THE MISSISSIPPI MINERAL RESOURCES INSTITUTE
Velon H. Minshew, Director
The University of Mississippi
University MS 38677

EVALUATION OF LANDSAT IMAGERY AS AN EXPLORATION TOOL IN PETROLEUM EXPLORATION IN MISSISSIPPI

by

Velon H. Minshew, MMRI

Tsean-shu P. Lee, MMRI

Conrad A. Gazzier, MMRI

Mississippi Mineral Resources Institute

University, Mississippi

Mississippi Mineral Resources Institute
University of Mississippi
University, Mississippi 38677

June, 1979

TABLE OF CONTENTS

	Page
LIST OF FIGURES	vii
INTRODUCTION	1
PREVIOUS WORKS	2
DESCRIPTION OF FACILITIES	4
THE LANDSAT IMAGERY	5
OBJECTIVES	5
PROCEDURES	6
GENERAL GEOLOGY	11
PHYSIOGRAPHY	11
Southern Pine Hills	11
Pine Meadows (Pleistocene Coastal Terrace)	11
STRATIGRAPHY	11
REGIONAL TECTONICS	11
DISCUSSION	15
CONCLUSION	20
SELECTED REFERENCES	21

© 1981 BY THE MISSISSIPPI MINERAL RESOURCES

LIST OF FIGURES

Figure		Page
1.	Location Map	7
2.	State Wide LANDSAT Coverage	8
3.	LANDSAT Coverage of the Study Area	9
4.	Generalized Stratigraphic Section of the Study Area	12
5.	Generalized S-N Geologic Cross-Section Across Study Area	13
6.	Known Features of Study Area	16
7.	Generalized LANDSAT Derived Features of the Study Area (From Plate 1)	17
Plate 1		in pocket
Plate 2		in pocket

© 1981 BY THE MISSISSIPPI MINERAL

INTRODUCTION

Begin

During the past few decades the demand for natural resources has increased exponentially, but the reserves of such materials have dwindled, and the cost of exploration and extraction of such resources has increased. If our nation is to continue meeting the demands of society for energy and mineral resources, more efficient means of exploration are essential.

Geologic exploration techniques have increased in cost, as have most other goods and services. The investigation of LANDSAT imagery for energy and mineral resources holds promise of significantly reducing the costs of such exploration programs.

The University of Mississippi Mineral Resources Institute personnel initiated a program of evaluation of LANDSAT imagery be density slicing techniques utilizing visual interpretations of displayed images. The results of these studies have been most promising and have far surpassed the expectations of the researchers. Institute personnel report that it is possible to map geologic structures which may be buried beneath thousands of feet of overburden (Minshew, et al., 1978). MMRI researchers have successfully applied density slicing technology to surface mineral exploration in certain areas of the Gulf Coastal Plain.

End

© 1981 BY THE MISSISSIPPI

PREVIOUS WORKS

The University of Mississippi, Mississippi Mineral Resources Institute has been directly involved with remote sensing since 1973, carrying out an extensive evaluation of imagery and techniques. Low level funding from NASA during 1976 allowed research personnel to utilize equipment and imagery to survey several geologic areas in Mississippi where little structural information was available.

During the course of these studies, a buried structural anomaly was mapped near the small central Mississippi town of Possumneck. This anomaly was mapped through remote sensing technology, but at the time of mapping, the significance of the anomaly was unknown. Structural contour maps and cross-sections of the area indicated that the Teritary and Cretaceous sediments, which are about 8,000 feet thick, were flat-lying and undisturbed. No data were available regarding the nature of the underlying Paleozoic strata; therefore, the significance of the anomaly was not apparent.

In 1977, Ruddman, a drilling and oil exploration firm, announced plans to drill an exploratory wildcat well in the area of the Possumneck anomaly. Following the announcement, Amoco Production Company, New Orleans, Louisiana, a partner in the well, provided the MMRI a seismic profile of this area. The seismic data revealed a large breached dome overlain by several thousand feet of flat-lying sediments. Only at this time did it become apparent that the anomaly, as mapped by remote sensing, was the surface manifestation of a buried anticlinal structure.

The use of remote sensing as an aid for geologic interpretation in other Coastal plain areas has only been partially evaluated. Isphording and Riccio (1974) noted that major structural features in south Alabama could be identified as prominent lineaments. Although these investigators characterized these linear features as extentions of known faults, they were unable to field verify surface manifestation of all identified lineaments.

Fisk (1944) recognized a complex pattern of lineations in the unconsolidated Gulf Coast sediments of the Mississippi River valley region, and projected a series of suspected faults across Louisiana into the Mississippi coastal area.

Welby (1975) noted close agreement of LANDSAT derived data and structural trends previously noted by geologists in North Carolina in the early

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

1900's. While he stopped short of correlating specific lineaments with known zones of structural weaknesses, he observed that many of the lineaments are associated with geomorphic and topographic features.

Kreitler (1976) utilized conventional aerial photography to map lineations and faults in the Texas Coastal zone. Reid (1973) identified and correlated lineations and faults in the Houston, Texas area utilizing NASA color-infrared photography.

Probably the most definitive and useful work to date concerning the application of remote sensing to petroleum exploration was presented by Micheal T. Halbouty (1976) in the American Association of Petroleum Geologists Bulletin. Halbouty presented data confirming the value and use of LANDSAT as an inexpensive reconnaissance tool to oil explorationists and corporations.

At the present time, many of the developing countries of Africa and South America have and are utilizing LANDSAT data to evaluate remote unexplored regions prior to and sometimes in place of the more conventional seismic and gravity surveys.

Center

End

© 1981: BY THE MISSISSIPPI MINERAL RESOURCES INST.

DESCRIPTION OF FACILITIES

The Remote Sensing Laboratory at the University of Mississippi employs a System 130 Analysis System manufactured by Interpretation Systems Incorporated of Lawrence, Kansas. This is a video image-enhancement and analysis system developed to efficiently process large volumes of image data and produce readily interpretable enhanced imagery. A constant voltage transformer has been installed to provide stable voltage to the system. The system consists of a high resolution television camera mounted above a light table. The camera can be moved north-south and east-west to view the image and transmits a picture from a positive LANDSAT image through a VP-8 Image Analyzer. The VP-8 enables the researcher to separate and/or filter grey spectral values from the LANDSAT image. Eight false colors may be assigned to areas of similar selected spectral values, and the resulting image is displayed on a high-resolution Conrac Monitor. The image displayed on the monitor can be changed to the scale of any basemap from 1:62,500 to 1:500,000.

The VP-8 is also capable of isometric profiling. Grey spectral values received from the camera are assigned height values, and the resulting false "3-D" image is displayed on a Hewlett-Packard monitor. This image can be electronically rotated to permit viewing of an area from any direction and, at the same time, tilted to any angle from 0 to 90 degrees. This allows the researcher to view the surface in various perspectives. Our work indicated that the isometric projecting technique is a most important tool for mapping geologic structures.

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

THE LANDSAT IMAGERY

LANDSAT-1 (ERTS-1) was launched by the U. S. NASA on July 23, 1972. LANDSAT-2 was launched January 22, 1975. LANDSAT-3 was launched in March 1978. LANDSAT is stabilized in a near polar orbit approximately 570 miles above the earth in a sun-synchronous orbit which allows 14 orbits each day and coverage of each area every 18 days. The satellites contain two imaging systems, a Multispectral Scanner (MSS), and a Return-beam Vidicon (RBV).

The MSS is the primary sensor system. It acquires images of 115 mi. (185 km) per side in four spectral bands in the visible and near-infrared parts of the electromagnetic spectrum and overlap by 10 percent along the spacecraft track. The electronic signals are transmitted to the ground and converted to picture images. A pixel (picture element that is the smallest unit of LANDSAT image) covers 59 X 79 m^2, or $(200\ ft)^2$, on the ground. Spatial resolution for the images averages about 200 feet but is apparently higher for high contrast linear features.

OBJECTIVES

The objectives of this study were: (1) to evaluate the use of LANDSAT imagery for locating known geologic structures in geologically well known areas within the Mississippi Salt Embayment; (2) to apply these techniques to less well known areas within the State; (3) to prepare an interpreted tectonic map of these selected areas.

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

Begin

PROCEDURES

In order to ascertain if LANDSAT could be used to recognize geologic structures in humid coastal plain terrains, and to determine appropriate levels of confidence in interpretations, a preliminary investigation of selected areas within the tightly controlled Mississippi Salt Embayment was initiated. Of particular interest were the structural features near Tatum, Lampton, Richton and Cypress Creek Salt Domes, which are being studied by the Department of Energy. The results of this study were encouraging, and most of the known structures were mappable utilizing remote sensing. Band 7 (near infrared) was shown to provide the maximum geologic information. Following analysis of these areas, research was expanded to the less well known coastal area. Six counties were covered, including Jackson, Harrison, Hancock, George, Stone, and Pearl River (Figure 1).

A series of positive Multispectral-Scanner (MSS) transparent films of separate spectral band and color composites, covering the study area at a scale of 1:1,000,000 from the LANDSAT-1, and LANDSAT-2, were obtained from Earth Resources Observational Satellite (EROS) Data Center at Bay St. Louis, Mississippi (Figure 2). The MMRI has available enlarged prints at a scale of 1:250,000, and these were utilized for references. For this first-year study, two imageries were used: Path-23--Row-39 (NASA ERTS E-1285-16024-7-01) of May 4, 1973, and Path-22--Row-39 (NASA ERTS E-1176-15562-7-03) of January 15, 1973 (Figure 3). Basemaps of the study area were prepared from twenty-one 15 minute (1:62,500) and fourteen 7 1/2 minute (1:24,000) U.S.G.S. Topographic Quadrangle Maps. Unfortunately, complete coverage of the study area was not available at the 15 minute scale. The topographic maps enable the researcher to utilize both cultural and geographic features as location controls. The scale used in this study was 1:62,500, or about one inch equals a mile. At this scale, one CONRAC monitor picture (frame) covers approximately a 13 X 10 mile^2 area. The study area was thus divided into some forty frames with at least 10 percent overlap on each side of the frame. Each frame was then studied and mapped independently.

The procedure for maintaining reference point control involved locating a well-identified landmark, cultural, or geographic feature on the black and white CONRAC display and, in turn, locating that point on the topographic base-maps. By manipulating a set of cross hair (cursors) and adjusting the

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

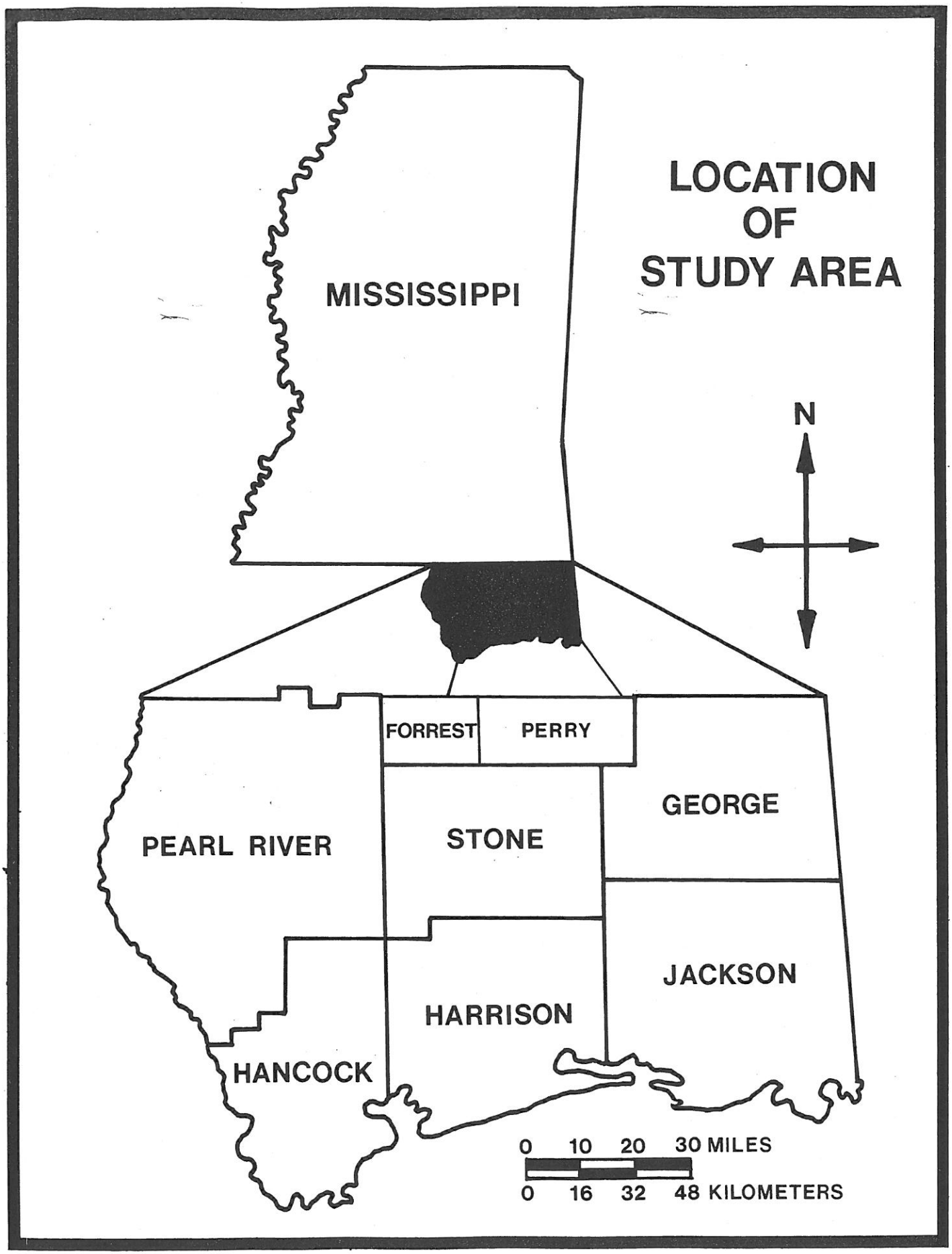


FIG.1: Location Map

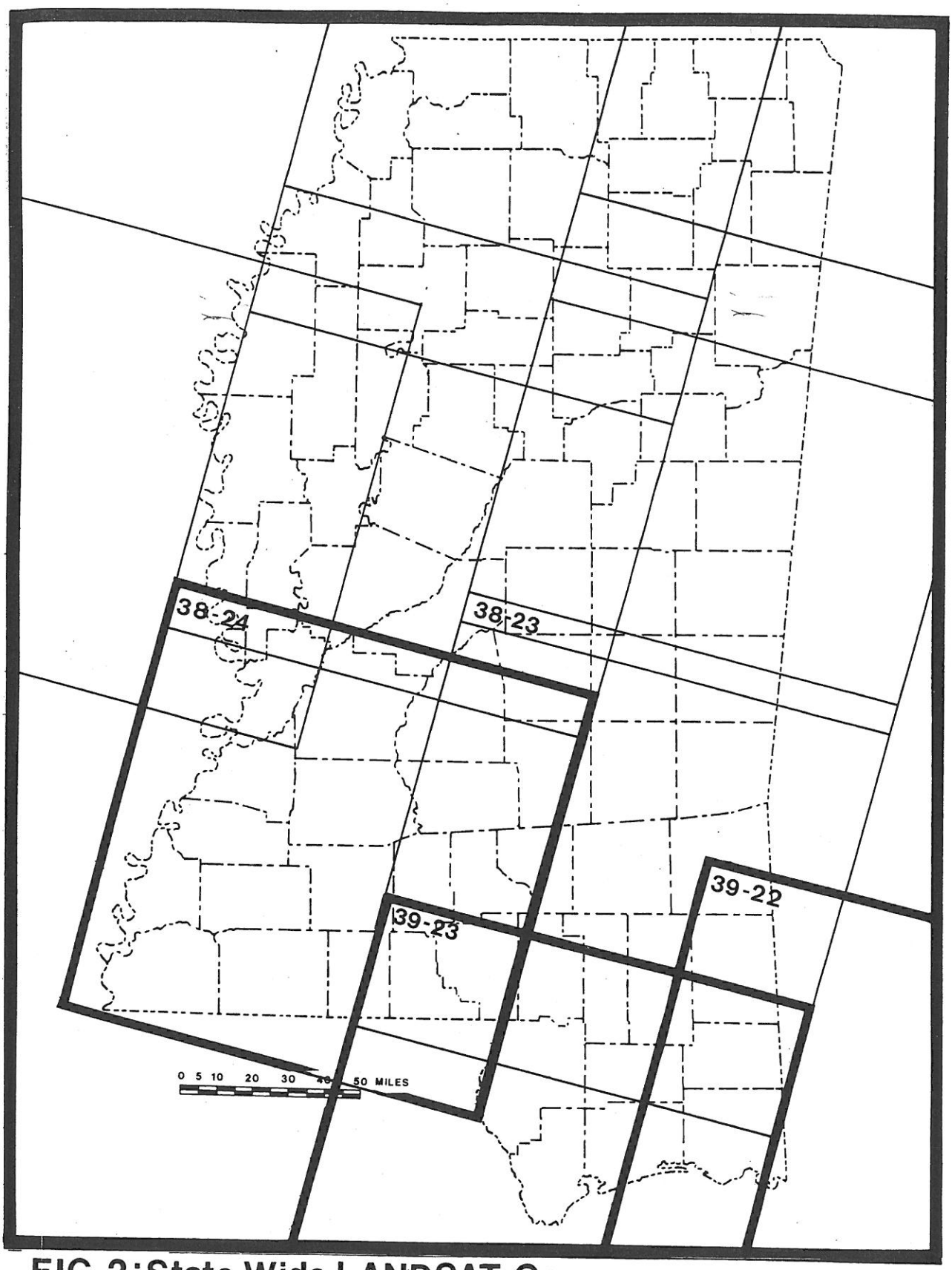


FIG. 2: State Wide LANDSAT Coverage.

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

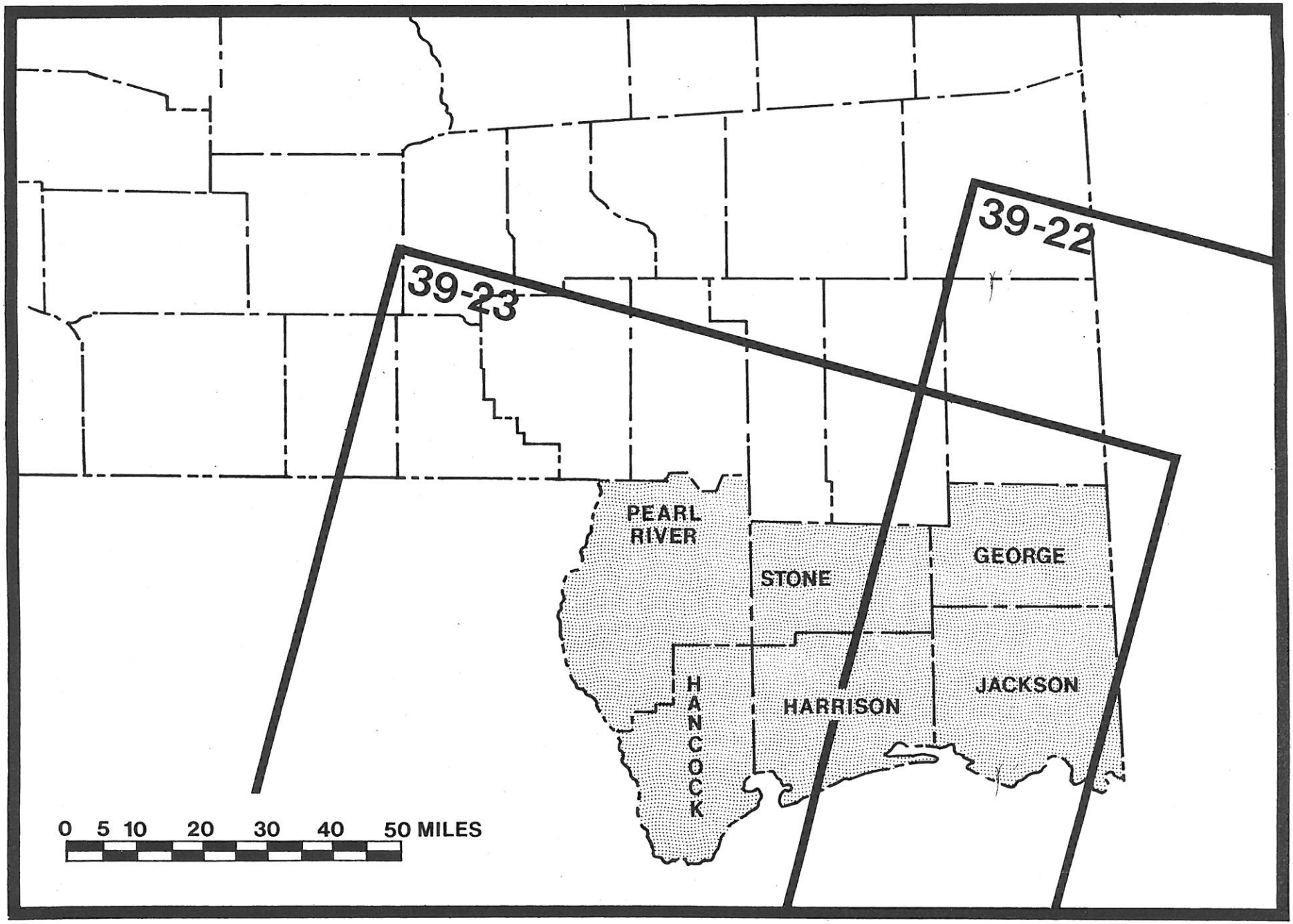


FIG. 3 : LANDSAT Coverage of Study Area

digital readout on the VP-8, the coordinates of any selected point on the frame can be located. Units of coordinates were set at one tenth of a mile, which is the accuracy of the interpretations. These data were manually transferred onto mylar basemaps.

Completed basemaps were overlaid on topographic quadrangle maps for the final compilation. Those features which were well defined were, in turn, rated as 1st order (Plate 1) and were differentiated from those less noticeable, which were rated as 2nd order (Plate 2).

One possible problem is that by using the 1:62,500 scale, circular features with diameters larger than 10 miles could very possibly be left out or be interpreted as curvilineations. Even some features with diameters less than 10 miles would be misinterpreted if, for instance, they were only partially covered by a frame. This problem, however, would exist, no matter how small the scale used, unless the study area could be covered in one single frame. In order to compensate for the above difficulties, an overall study at a scale of 1:250,000 was conducted for the final mapping. Visual interpretation was made from imageries, enlarged prints, and from topographic maps.

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

Physiography

The study area lies within the Gulf Coastal Plain Province. Thronburg (1965) described two physiographic units in the six southern counties: the Southern Pine Hills and Pine Meadows (Pleistocene Coastal Terrace).

Southern Pine Hills. This is a cuesta-like unit covering most of the Mississippi Salt Embayment and the north half of the study area. The region is a naturally-dissected upland, which slopes southward from altitudes about 400 to 500 feet on the north and west, to about 200 feet at the southern margin (Pine Meadows). The surficial sediments in this region are alternating beds of clay, sandy clay, and sands of Miocene and Pliocene age, with gravel and sand of the Citronelle Formation occurring discontinuously.

Pine Meadows (Pleistocene Coastal Terrace). Between the Pine Hills and Mississippi Gulf Coast lies a narrow band of Pleistocene age marine terraces in elevation from about 200 feet in the north to sea level at the coast. Several low sand ridges (of marine origin) rise above the plain near the coast. There are extensive tracts of swamps and marsh adjacent to the coast, and extending inland along the major streams.

Stratigraphy

The study area is underlain by unconsolidated sediments which dip gently toward the south and west. The stratigraphic section (Figure 4) across the area varies in age from Jurassic to Recent. Figure 5 shows the general stratigraphy from north to south. The Wiggins Uplift, a regional structural element, interrupts the southwestern dip of the beds. Louann Salt and other Jurassic units are pinched out at the Wiggins Uplift, while Cretaceous and younger strata thin over it. South of the Uplift, sedimentary units generally thicken Gulfward.

Regional Tectonics

The dominant structural element of the area is the Wiggins Uplift (Figure 6), an irregular, partly arcuate structural high during the Mesozoic and Cenozoic Eras. It consists of a northwest-southeast elongate ridge system connecting positive tectonic elements from around the Natchez Uplift eastward across the Baxterville and Pistol Ridge oil fields into Stone

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

ERA	SYSTEM	SERIES	GROUP OR FORMATION
CENOZOIC	Quaternary	Recent Pleistocene	Alluvium Citronelle
	Tertiary	Miocene	Pascagoula Hattiesburg Catahoula
		Oligocene	Vicksburg Forest Hill
		Eocene	Jackson Claiborne Wilcox
		Paleocene	Midway Clayton
MESOZOIC	Cretaceous	Gulf	Selma Eutaw Tuscaloosa
		Comanche	Washita- Fredericksburg Paluxy Mooringsport Ferry Lake Rodessa Pine Island Sligo
		Coahuila	Hosston
	Jurassic		Cotton Valley Haynesville- Buckner Smackover Norphlet Louann Werner
	Triassic		Eagle Mills
PALEOZOIC	Pennsylvanian Mississippian Devoian Silurian Ordovician Cambrian		

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

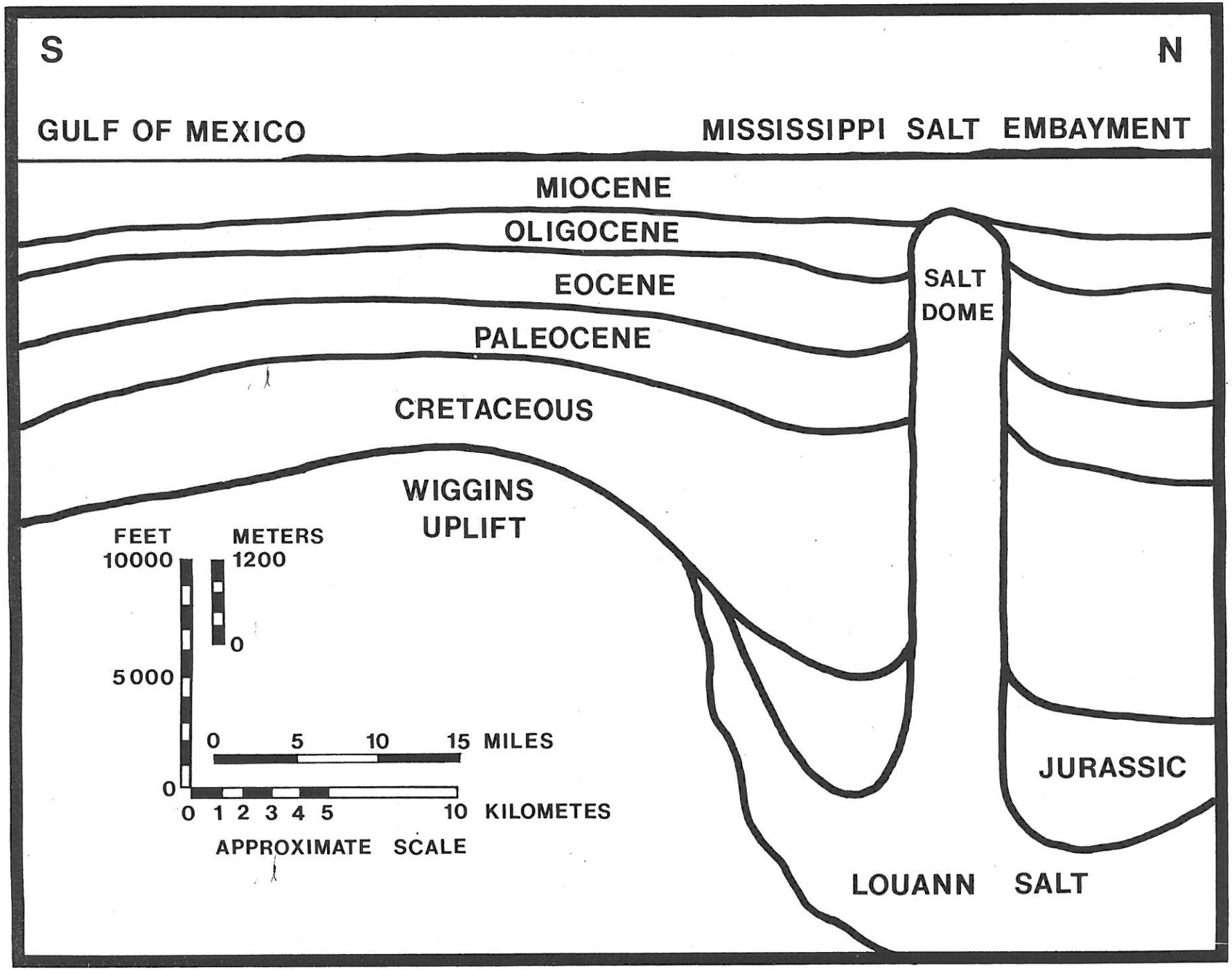


FIG.5 : Generalized S-N Geologic Cross-Section Across Study Area

County, Mississippi. From Stone County eastward into Alabama the extension is poorly defined. The anticlinical structure appears to difurcate in Stone County, forming the Hancock Arch, which trends southwest through Hancock County (Murray, 1961). The Lucedale Dome occurs about twenty miles east of the Wiggins Uplift, but the relationship of the two is speculative. It is thought that it may be a part of a major structural complex extending southeastward into Mobile County, Alabama.

Beall (1973) proposed that this area was under compressional stress from the southeast from late Precambrian through Paleozoic time. As a result, northwest-trending faults developed along the coast. These compressional stresses were replaced by tensional stress as the Mesozoic Gulf Basin was formed. Grabens and other fault structures were formed along zones of crustal weakness. The major direction of tension appears to have been in a north-south direction with major grabens striking northwest and secondary components to the northeast. The faults are thought to have been growing during the Triassic deposition.

The Wiggins Uplift, which separates the Interior and Coastal Salt Basins, may be a part of an old land mass which was left behind during the plate movements (plate tectonics). The main deposition centers appeared to have been bounded between the Pickens-Gilbertown fault zone and the Wiggins Uplift. The salt domes and the deposition of Jurassic sediments were restricted between these boundaries. Through time, sediments covered the Wiggins Uplift and the main centers of deposition moved southward. The most common type of structural feature in the coastal area is the down-to-the-basin fault, induced by gravity slumping (Beall, 1973).

End

© 1981: BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

DISCUSSION

Plates 1 and 2 (in pocket) show the 1st order and 2nd order anomalies interpreted from LANDSAT imageries. Figure 7 is a generalized illustration of the 1st order features.

The lineaments identified by remote sensing in the Mississippi Coastal area are present in two distinct subparallel sets or bands. The most obvious ones strike northwest, and the other northeast. The two sets intersect each other at high angles (from 55° to 110°).

The most conspicuous tectonic feature of the study area is the Wiggins Uplift (basement structure), which is well outlined by the drainage patterns of Red and Black Creeks. It is characterized by a series of lineaments which strike northwest across the LANDSAT image. One of these lineaments bounds the southern edge of the uplift. The uplift appears to trend northwest. Inside the regional uplift (Wiggins), a number of smaller anomalies were identified. These are interpreted as a series of smaller domes or anticlinal structures.

The Lucedale Dome is recognizable by the anomalous changes in the course of the Pascagoula and Escatawpa Rivers around the edge of the Dome. Lineaments are also present in the vicinity of Lucedale, MS. They seem to be a part of a major structural complex extending southeastward into Mobile County, Alabama (Minshew, et al., 1978). Inside this regional structure is a series of smaller concentric anomalies, some bounded by lineaments (Figures 6 and 7, Plates 1 and 2).

A series of major lineaments is present striking about N55°W to the southwest of the Wiggins Uplift from near Biloxi Bay northwest toward Pistol Ridge and Baxterville oil fields. Other parallel sets present to the southwest strike about N34°W from near Bay St. Louis across Pearl River County into Louisiana.

The northeast striking lineaments in coastal Mississippi are less well developed than those which strike northwest. The most clearly defined series originates near Lucedale and is traced to the southwest to near New Orleans, Louisiana. Another series of short lineaments strikes about N57°E in the eastern part of George and Jackson Counties and extends to the southern part of Harrison County. These lineaments are disturbed by circular anomalies or by northwest striking lineaments. A few short lineaments, striking about

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

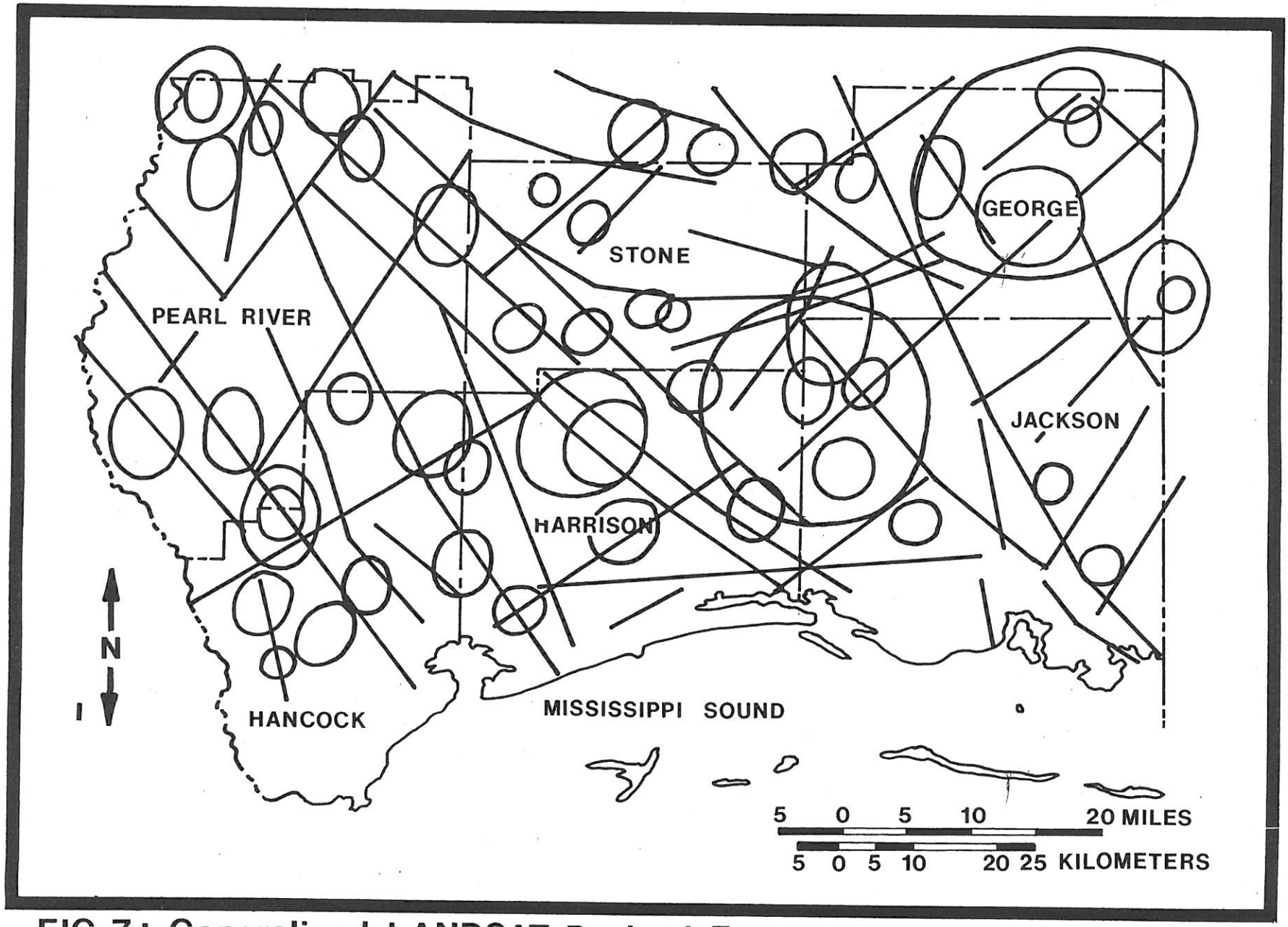


FIG. 7 : Generalized LANDSAT Derived Features Of The Study Area (From Plate 1)

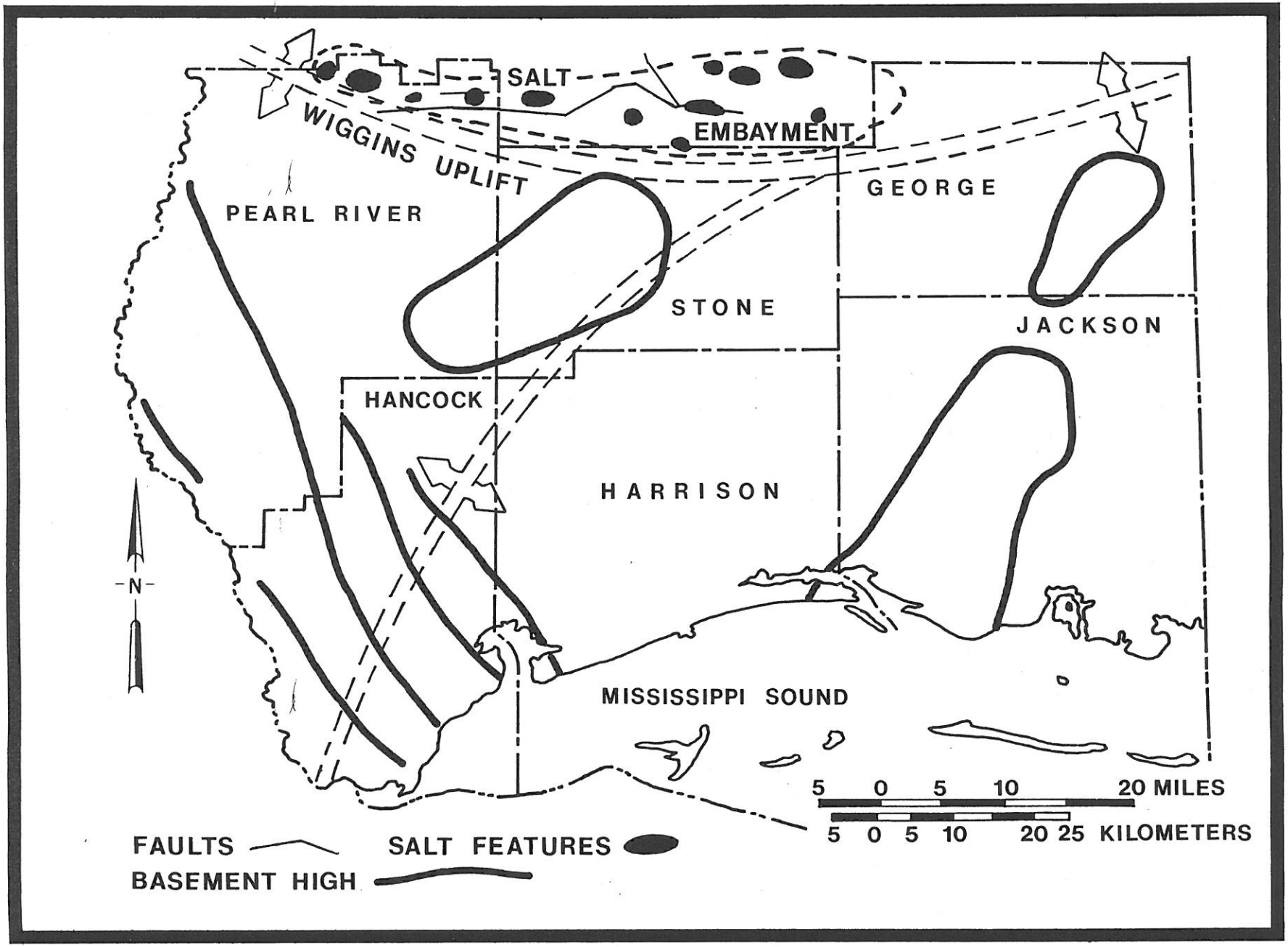


FIG. 6: Known Features Of Study Area (Generalized)

15. Reid, W. M. (1973), Active Faults of Houston, Texas, Univ. Texas, Austin, Ph.D. Dissertation, p. 122.

16. Thornburg, W. D. (1964), Regional Geomorphology of the United States, John Wiley & Sons, Inc., New York, p. 122.

17. U. S. Geological Survey (1974), The EROS Data Center, Pamphlet.

18. Welby, C. W. (1975), LANDSAT-1 Imagery for Geologic Evaluation Photogrammetric Engineering and Remote Sensing, Vol. XLII, pp. 1411-1422.

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

the same direction, appear in western Stone County but are interrupted by the northwest trending lineaments. These are correlated with basement highs indicated by gravity data. A series of less well defined lineaments strikes about N30°E, appearing in Pearl River County. One lineament identified strikes almost north-south.

A series of anomalies is recognizable along the projected trend of the Hancock Arch extending southwestward from the Wiggins Uplift. A series of lineaments is barely noticeable and parallel the position of the Arch (Plate 2). The most prominent feature associated with this structure is a series of circular anomalies centered around T5E, R12W (Figure 6, Plate 1). Another regional structure is located directly to the east of these features, centered around T5S, R9W, (Figure 6, Plate 1). The northward flow of Red Creek in this area closely parallels this anomaly. An unusual east-west striking lineament has been identified in the southern part of Harrison and Jackson Counties. It can be traced into Mobile County, Alabama, where it coincides with the southern edge of the erosional Citronelle Escarpement. Several man-made features (US Highway 90 and I-10) also parallel this lineament, indicating a possible cultural origin. The coastal line is parallel with the lineaments in many places.

The remote sensing derived maps of the Mississippi Coastal area were compiled without regard to the known data in this area. Subsequent to the preparation of these maps, the data were compared with known tectonic features of the Gulf Coast (AAPG, 1972), unpublished gravity data, surficial geologic maps, topographic quadrangles, and structural contour maps defining the configuration of the Lower Tuscaloosa Formation (Engineering Service, 1960). Figure 6 is a generalized map of the known features of the study area. Most of the known features were recognizable on the LANDSAT images, but a large number of the features on the image are not represented on the existing geologic maps.

On a regional basis, the dominant lineaments trend generally parallel with the trend of deflections in contours of gravity data in the area, parallel to structural contours, and coincide with the general trend of the geology and topography of the area. Some of the anomalies can be explained from topographic features. Many of the circular features correspond well with gravity anomalies.

End

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

The AAPG tectonic map of this area is monotonic, but when compared with LANDSAT anomaly data, the lineaments in the western part of the study area and the Wiggins Uplift can be well correlated. A comparison of the locations of producing oil and gas fields with the imagery features reveals that the producing trends are along identified linear or within circular anomalies.

CONCLUSION

While the significance of the northwest striking lineaments across the coastal zone has not yet been totally demonstrated, they are parallel with known Jurassic ridge systems to the immediate north of the study area. The northeast striking lineaments are perpendicular to these ridge systems and closely paralled gravity anomalies. The most logical explanation is that these lineaments are surface expressions of zones of structural weaknesses and the parallelism of the remote sensing derived features and the known structural elements is suggestive of tectonic control.

Although the exact causes of the recognition patterns are imperfectly understood, it is clear that the configuration of the subsurface structures do have surface expressions or manifestations and are recognizable on LANDSAT imagery. LANDSAT data also suggests that the structure is far more complex in this area than that reflected by existing subsurface contour maps. The authors of this report believe that it is possible to map these buried structures through remote sensing density slicing techniques, and, where other types of data are available, they should be utilized to enhance the LANDSAT interpretations. If, however, such data is not available, the analysis of LANDSAT imagery can provide valuable insights into regional tectonic patterns. This study supports the continuation of remote sensing investigations in Mississippi and perhaps a reevaluation of current subsurface correlations and interpretations.

© 1981: BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE

SELECTED REFERENCES

1. Beall, R. (1973), Plate Tectonics and the Origin of the Gulf Coast Basin, Gulf Coast Asso. of Geological Societies, Transaction, Vol. XXIII, pp. 109-114.

2. Bechtel National, Inc. (1978), Regional Environmental Characterization Report for the Gulf Interior Region and Surrounding Territory.

3. Engineering Service (1960), Regional Subsurface Map Countered on Top of Lower Tuscaloosa Formation, 1 sheet, scale 1:125,000.

4. Fisher, V. N. (1974), Cross Section from Mississippi-Tennessee State Line to Horn Island in Gulf of Mexico, Mississippi Geol. Survey.

5. Fisk, H. N. (1944), Geological Investigations of the Alluvial Valley of the Lower Mississippi River, U. S. Army Corps of Engineers, Mississippi River Commission, p. 78.

6. Gulf Coast Association of Geological Societies and American Association of Petroleum Geologists (1972), Tectonic Map of Gulf Coast Region, U.S.A., 1 sheet, scale 1:1,000,000.

7. Halbouty, M. T. (1976), Application of LANDSAT Imagery to Petroleum and Mineral Exploration, America Association of Petroleum Geologists, Bull., Vol. 60, pp. 745-793.

8. Isphording, W. C. and Riccio, J. F. (1974), Use of Satellite Imagery in Interpretation of Physiographic and Structural Features in South Alabama, Am. Asso. Petroleum Geologists.

9. Kreither, C. W. (1976), Lineations and Faults in the Texas Coastal Zone, Bureau of Economic Geology, Univ. of Texas at Austin.

10. Minshew, V. H., Gazzier, C. A., Malbrough, L. P. and Pellegrin, F. J. (1978), Resource Capability Analysis of the Mississippi Coastal Zone (Pre-Publication), Mississippi Mineral Resources Institute, University of Mississippi, p. 289.

11. Minshew, V. H., Frederking, R. L., Staheli, A. C. and Gazzier, C. (1978), Possumneck, Mississippi: Anatomy of a Buried Structural Anomaly, Abstracts with Programs, Southeastern Sec. of Geo. Soc. of Am., 27th Annual Meeting, p. 176.

12. Mississippi Geological Survey (1969), Geologic Map of Mississippi, 1 sheet, scale 1:500,000.

13. Murry, G. E. (1961), Geology of the Atlantic and Gulf Coastal Province of North America, Harper & Brothers, New York.

14. Oxley, M. L. and Minihan, E. D. (1969), Jurassic Stratigraphy of Alabama and Panhandle Florida, an abridged paper presented at a Gulf Coast Asso. of Geological Societies' covention.

© 1981; BY THE MISSISSIPPI MINERAL RESOURCES INSTITUTE